MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2019/2020

EEL2216 – CONTROL THEORY

(All sections / Groups)

23 OCTOBER 2019
9.00 a.m – 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of **SEVEN** pages including cover page with **FOUR** questions only.

2. Answer **ALL** questions and print all your answers in the answer booklet provided.

3. All questions carry equal marks and the distribution of the marks for each question is given.

Question 1

(a) A particular control system has a second order differential equation given as,

$$2\frac{d^2y(t)}{dt^2}+8\frac{dy(t)}{dt}+8y(t)=x(t),\quad x(t)=10u(t).$$

Assume zero initial conditions,

(i) solve the above differential equation. [8 marks]

(ii) calculate the final value of $y(t)$. [2 marks]

(b) Define and elaborate the meaning of open-loop and closed-loop system. [4 marks]

(c) Derive the transfer function $C(s)/R(s)$ for the signal flow graph as shown in Figure Q1 by using Mason's rule. [11 marks]

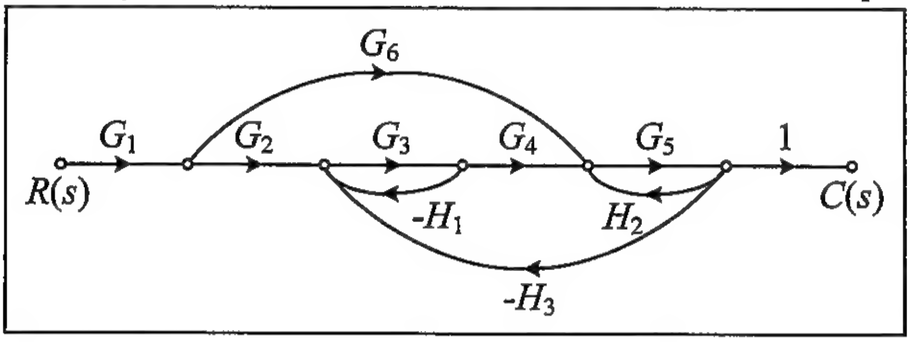

Figure Q1

Continued...

Question 2

(a) Given a unity feedback control system with an open-loop transfer function:

$$G(s) = \frac{1}{2s^5 + 3s^4 + 2s^3 + s^2 + 2s + 2}$$

(i) Use Routh-Hurwitz Criterion to determine the number of poles on the left half plane and right half plane. [9 marks]

(ii) Comment and evaluate on the stability of the system. [1 marks]

(b) Given that a unity feedback control system has a forward-transfer function $G(s)$

$$G(s) = \frac{500}{(1+0.5s)(1+5s)}$$

(i) Determine the error constants (k_p, k_v, k_a). [6 marks]

(ii) Calculate the steady state error for a unit step input $u_s(t)$, unit ramp input $tu_s(t)$, and parabolic input $\frac{t^2}{2}u_s(t)$. [3 marks]

(c) Consider a unity feedback control system shown in Figure Q2.

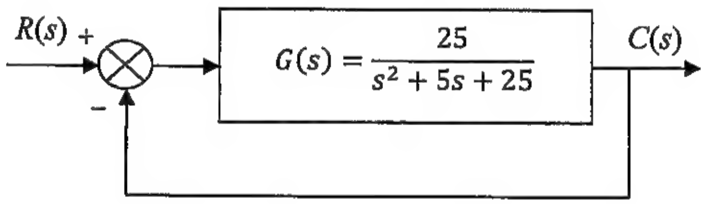

Figure Q2

(i) Calculate the undamped natural frequency and damping ratio. [4 marks]

(ii) Determine whether the system is overdamped, critically damped or underdamped. [2 marks]

Continued...

Question 3

(a) In a control system with feedback loops, the system is able to adjust its performance to meet a desired output response by continuously monitoring the output throughout the process. As a control engineer, closed-loop stability has to be ensured. Define

i. Resonant peak. [2 marks]
ii. Phase crossover. [2 marks]
iii. Resonant frequency. [2 marks]
iv. Phase crossover frequency. [2 marks]

(b) A processing plant can be represented by a block diagram as shown in Figure Q3.

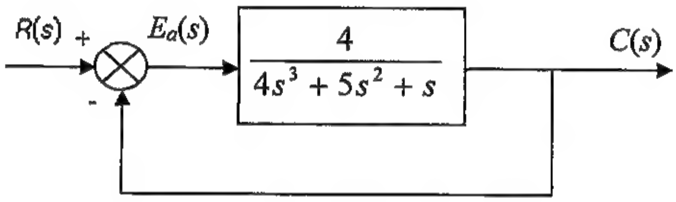

Figure 3.1

(i) Rewrite the loop transfer function and represent it in terms of $j\omega$. [4 marks]

(ii) Determine the magnitude response of the loop transfer function. [3 marks]

(iii) Determine the phase response of the loop transfer function. [3 marks]

(iv) Estimate the magnitude and phase when $\omega = 0$ and when $\omega = \infty$. [2 marks]

(v) Sketch the Nyquist diagram and determine if the system is stable [5 marks]

Continued...

Question 4

(a) In controller/compensator design, several configurations for control system compensation are available. Examples are cascade compensation and feedback compensation. Compare the differences by sketching the configurations of feedback compensation and cascade compensation. [6 marks]

(b) Explain the three terms of PID controller using a diagram. Compare and summarize it using a table on what is the effect of K_p, K_i and K_d to the control system's rise time, overshoot, settling time and steady state error. [9 marks]

(c) A system with a plant transfer function, $(s) = \frac{50}{s^2+8s+15}$, is shown in Figure Q4. Given that a PD controller has a transfer function of $K_{PD}(s) = k_a s + k_b$. Design K(s) as a PD controller if the system requires a damping ratio, $\xi = 0.8$ and an undamped natural frequency, $\omega_n = \frac{15rad}{s}$. [10 marks]

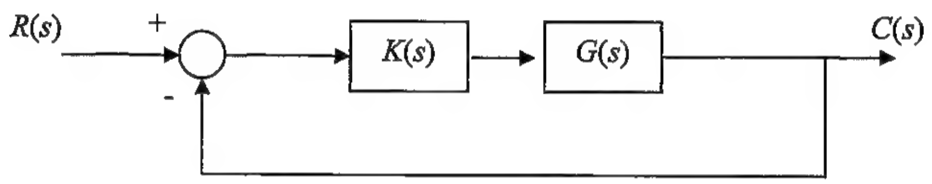

Figure Q4

Continued...

Appendix - Laplace Transform Pairs

$f(t)$	$F(s)$
Unit impulse $\delta(t)$	1
Unit step $1(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!} \quad (n = 1, 2, 3, \ldots)$	$\frac{1}{s^n}$
$t^n \ (n = 1, 2, 3, \ldots)$	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\frac{t^{n-1}}{(n-1)!}e^{-at} \quad (n = 1, 2, 3, \ldots)$	$\frac{1}{(s+a)^n}$
$t^n e^{-at} \ (n = 1, 2, 3, \ldots)$	$\frac{n!}{(s+a)^{n+1}}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$\sinh \omega t$	$\frac{\omega}{s^2-\omega^2}$
$\cosh \omega t$	$\frac{s}{s^2-\omega^2}$
$\frac{1}{a}(1-e^{-at})$	$\frac{1}{s(s+a)}$
$\frac{1}{b-a}(e^{-at}-e^{-bt})$	$\frac{1}{(s+a)(s+b)}$
$\frac{1}{b-a}(be^{-bt}-ae^{-at})$	$\frac{s}{(s+a)(s+b)}$
$\frac{1}{ab}\left[1+\frac{1}{a-b}(be^{-at}-ae^{-bt})\right]$	$\frac{1}{s(s+a)(s+b)}$

Continued...

Appendix - Laplace Transform Pairs (continued)

$\frac{1}{a^2}(1-e^{-at}-ate^{-at})$	$\frac{1}{s(s+a)^2}$
$\frac{1}{a^2}(at-1+e^{-at})$	$\frac{1}{s^2(s+a)}$
$e^{-at}\sin\omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
$\frac{\omega_n}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin\omega_n\sqrt{1-\zeta^2}\,t$	$\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$
$-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t-\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{s}{s^2+2\zeta\omega_n s+\omega_n^2}$
$1-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t+\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{\omega_n^2}{s(s^2+2\zeta\omega_n s+\omega_n^2)}$
$1-\cos\omega t$	$\frac{\omega^2}{s(s^2+\omega^2)}$
$\omega t-\sin\omega t$	$\frac{\omega^3}{s^2(s^2+\omega^2)}$
$\sin\omega t-\omega t\cos\omega t$	$\frac{2\omega^3}{(s^2+\omega^2)^2}$
$\frac{1}{2\omega}t\sin\omega t$	$\frac{s}{(s^2+\omega^2)^2}$
$t\cos\omega t$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$
$\frac{1}{\omega_2^2-\omega_1^2}(\cos\omega_1 t-\cos\omega_2 t)\quad(\omega_1^2\neq\omega_2^2)$	$\frac{s}{(s^2+\omega_1^2)(s^2+\omega_2^2)}$
$\frac{1}{2\omega}(\sin\omega t+\omega t\cos\omega t)$	$\frac{s^2}{(s^2+\omega^2)^2}$

End of Paper